



Photosynthetic Spectra on Exoplanets

Pigment Spectra for Organisms Living Around F, G, K, and M
Stars

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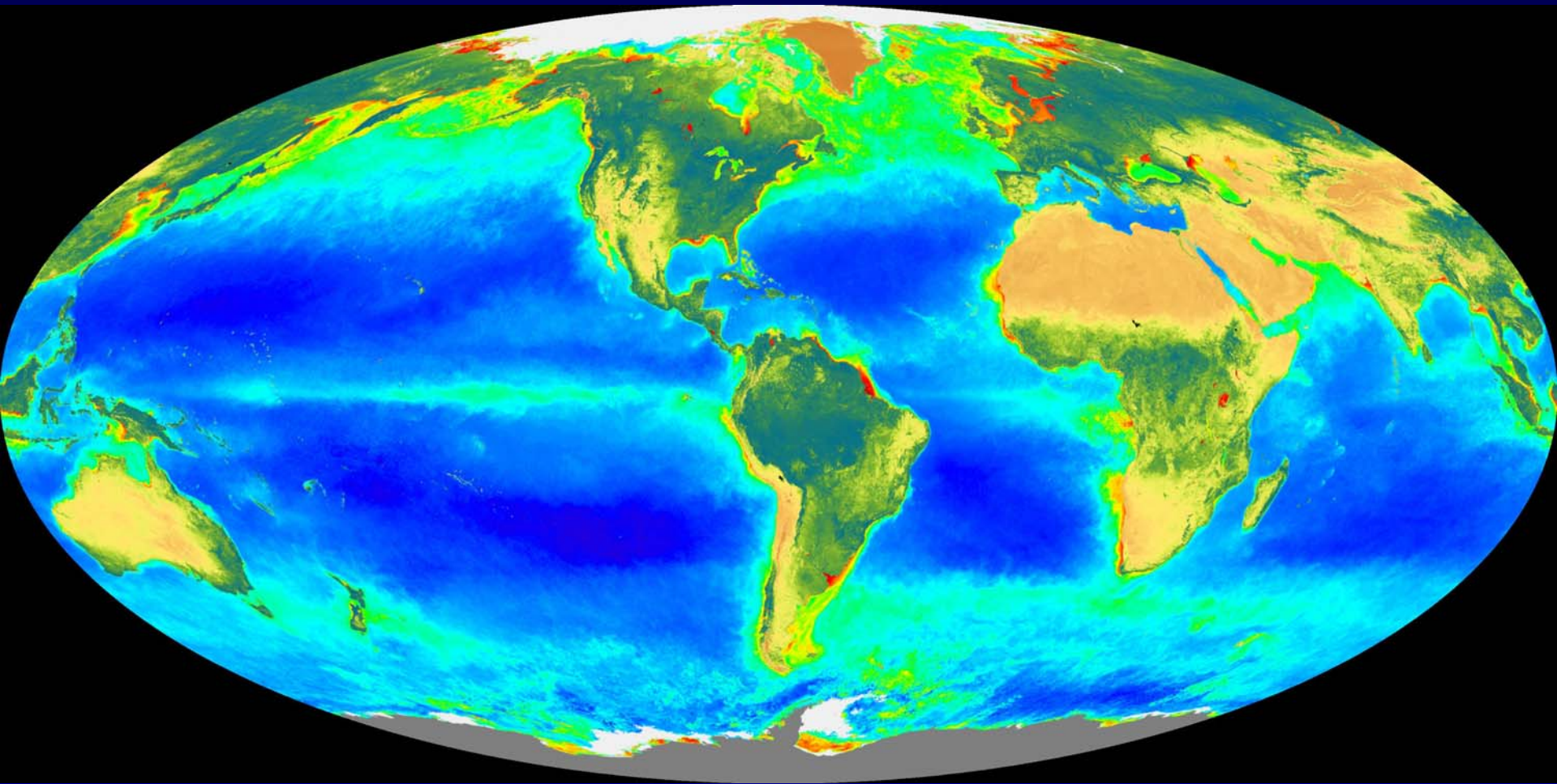
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SeaWiFS NDVI $(\text{NIR}-R)/(\text{NIR}+R)$: Vegetation red edge





Purple palm trees on planets around ?? stars?



THIS TALK:

- Explain chlorophyll dominance on Earth
(this really takes an hour to explain)
compare different pigment absorbance spectra
and Earth through time
- Simulations of light environments on
planets around F, flaring M, and quiescent
M stars
atmospheres from coupled 1D photochemical/radiative-
convective model, Pavlov & Kasting et al; spectra via
SMART radiative transfer model, Crisp & Meadows

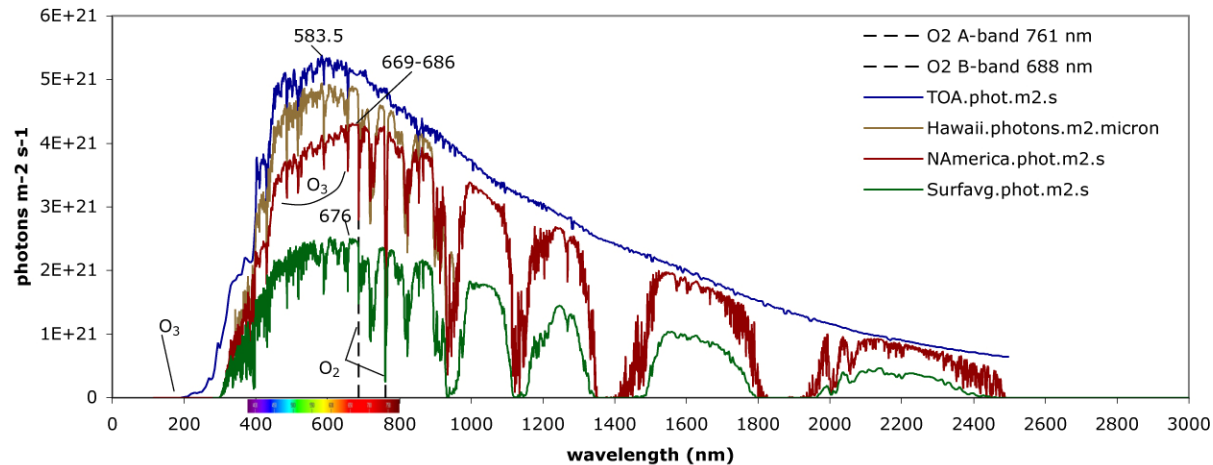


Photosynthetic pigments **must be adapted to the** available light spectrum,
resulting from:

- > photon flux spectrum of the parent star
- > filtering through a different atmosphere

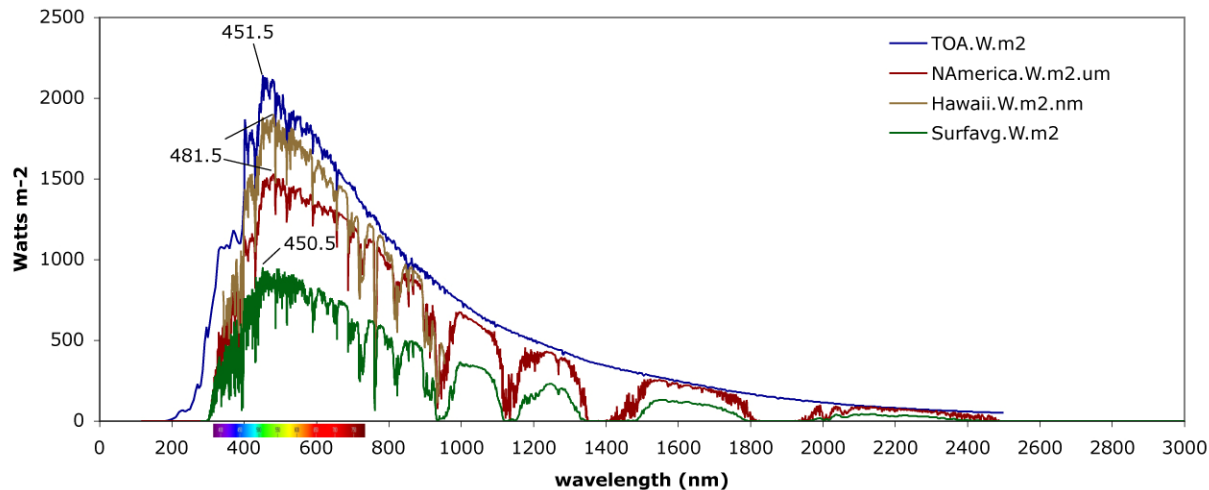
Photons vs. Energy

solar incident radiation - photon flux spectrum



Solar surface incident **photons** most abundant in the red:
-photosynthesis counts photons
- red is also the lowest-energy photon in the visible

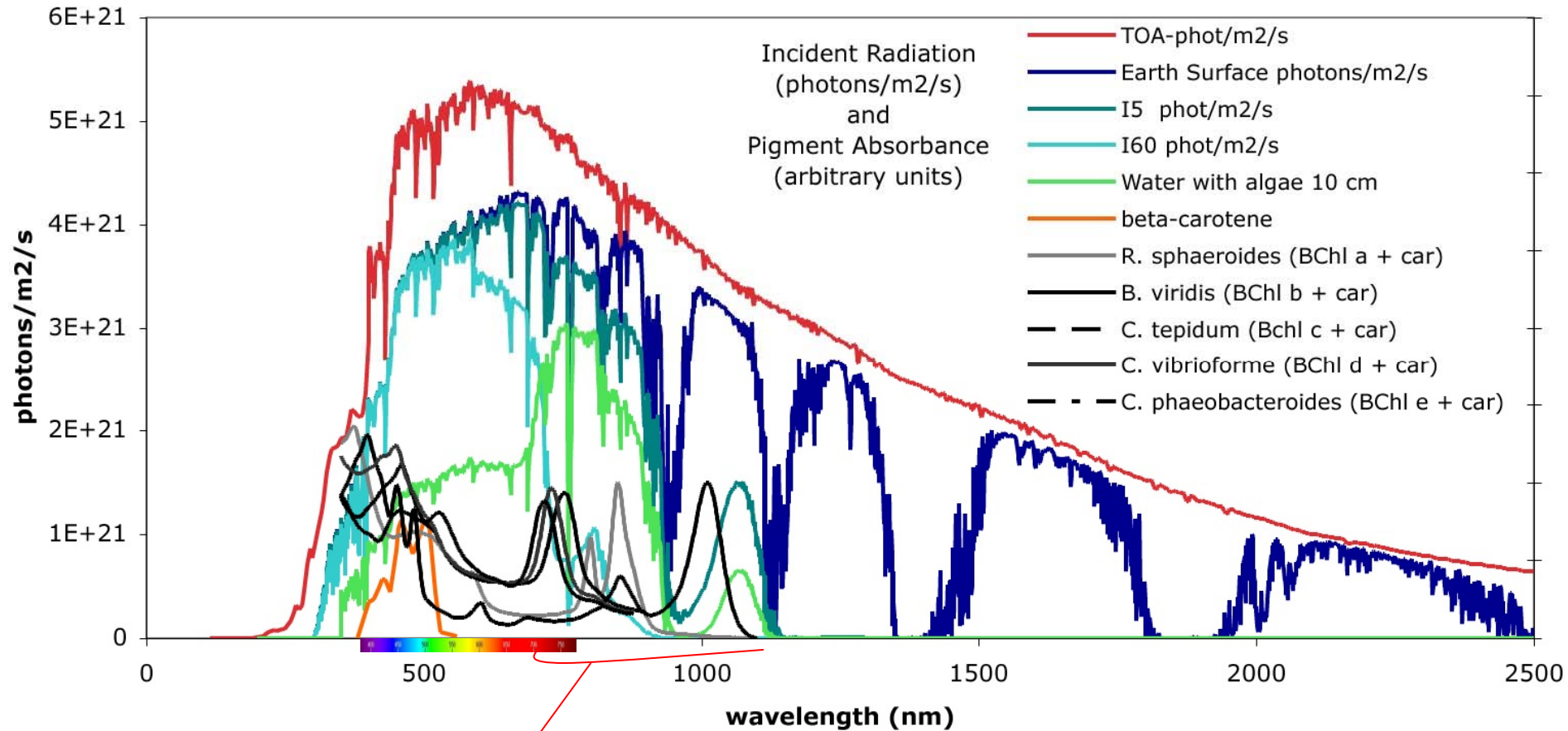
solar incident radiation - energy flux spectrum



Solar surface incident radiation most **energy** in
-> blue (~480 nm) =
Chl b secondary peak
-> indigo (~450 nm) =
Chl a secondary peak



3.4 Ga: Early photosynthesis under water & anoxygenic & infrared

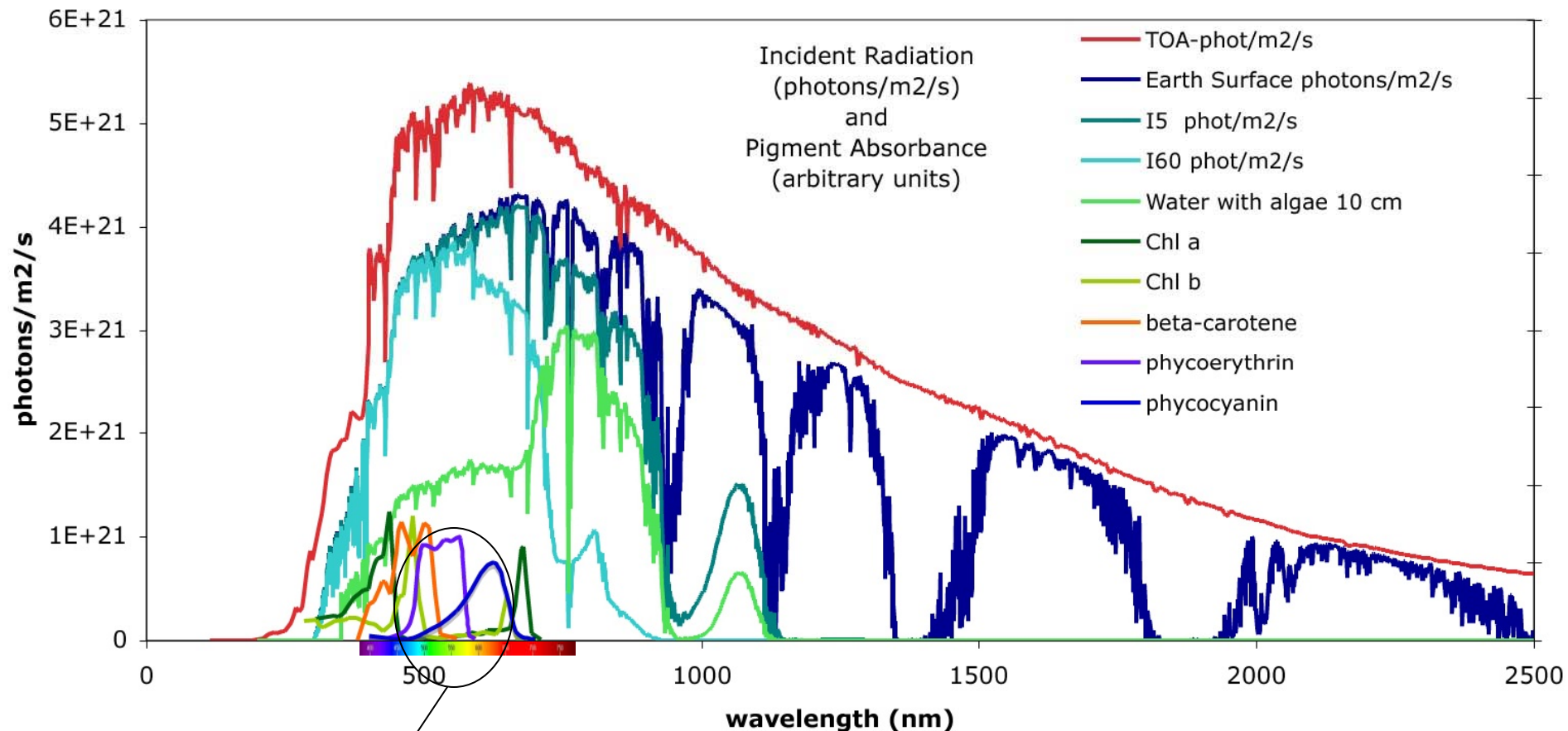
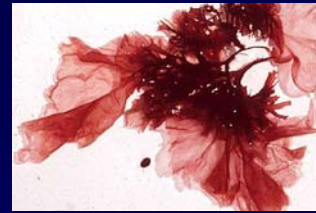
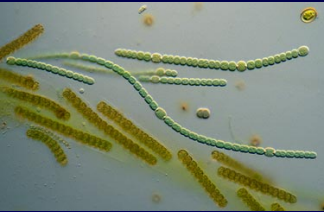


Photosynthesis in the infrared

2.7 Ga: Oxygenic cyanobacteria

1.2 Ga: Red and brown algae

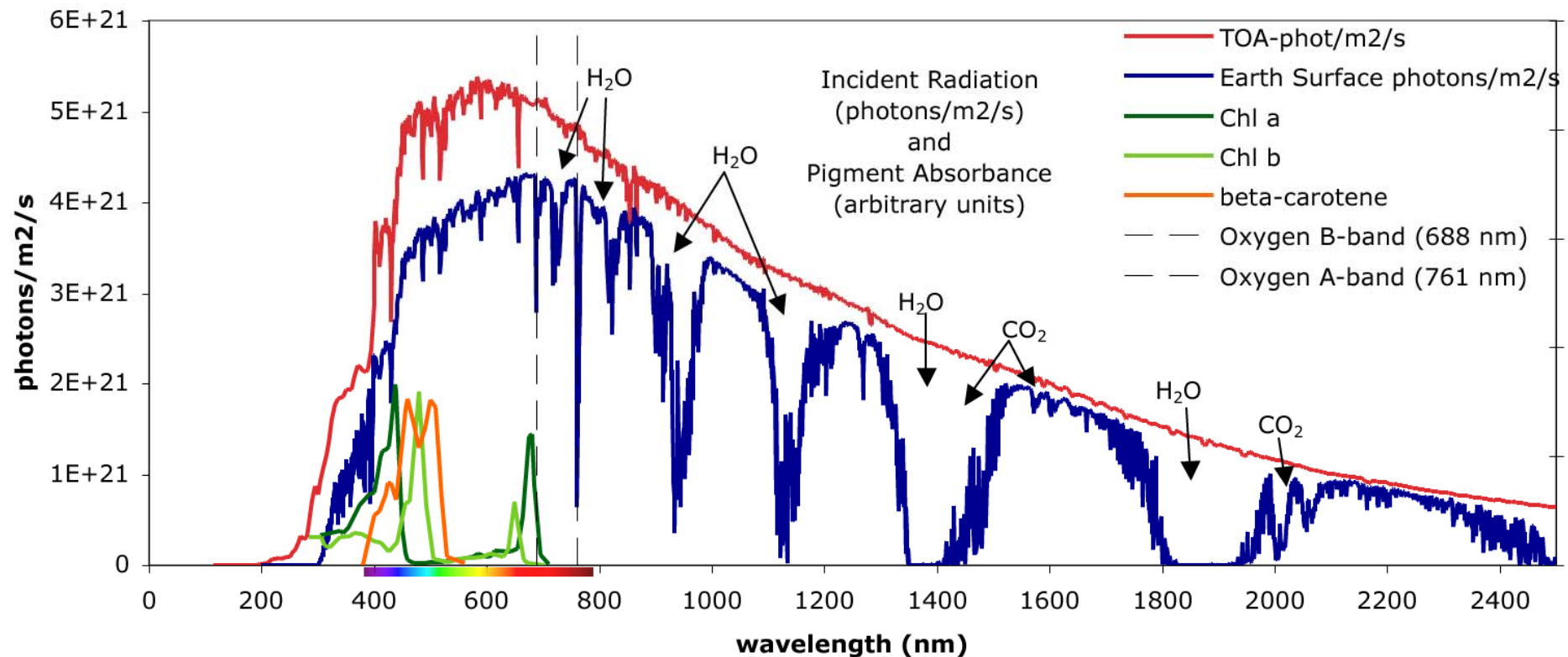
Still under water



phycobilins fill in the visible



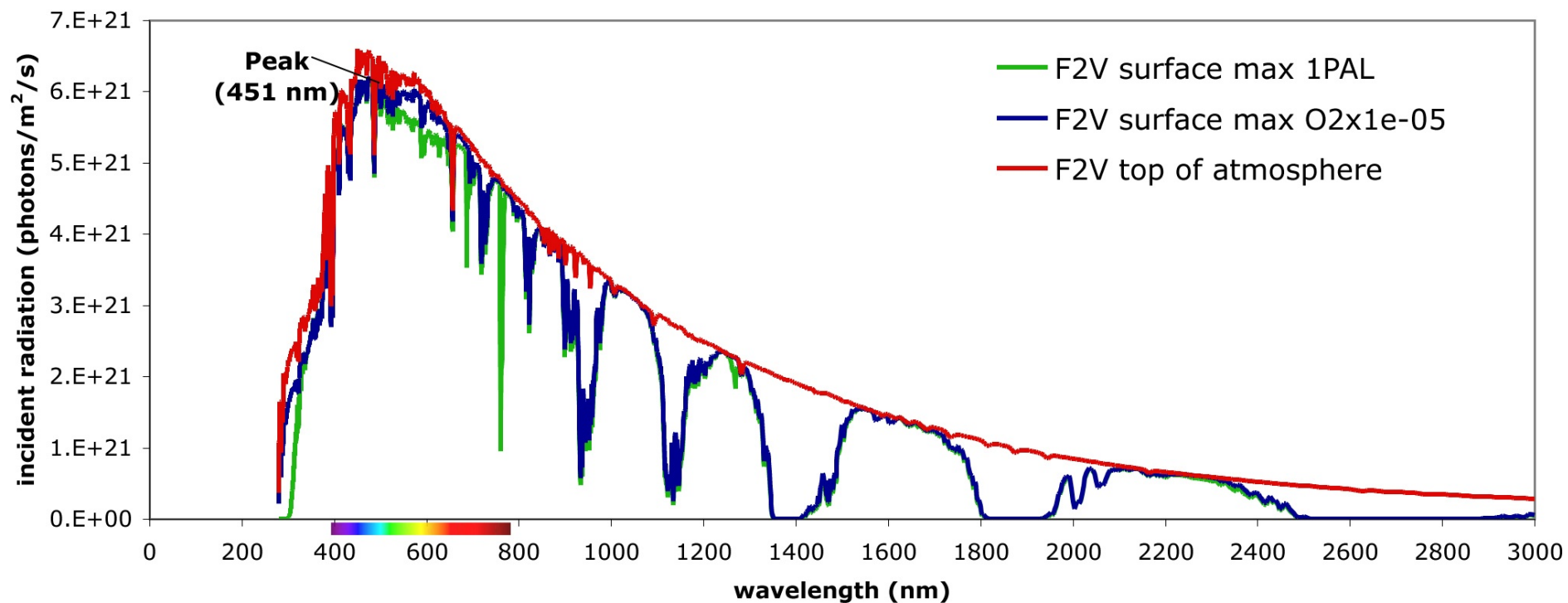
0.750 Ga - green algae
 0.475 Ga - first land plants
 ozone layer, too much light
 only chlorophyll and carotenoids





F2V star: ozone enhances peak in the blue

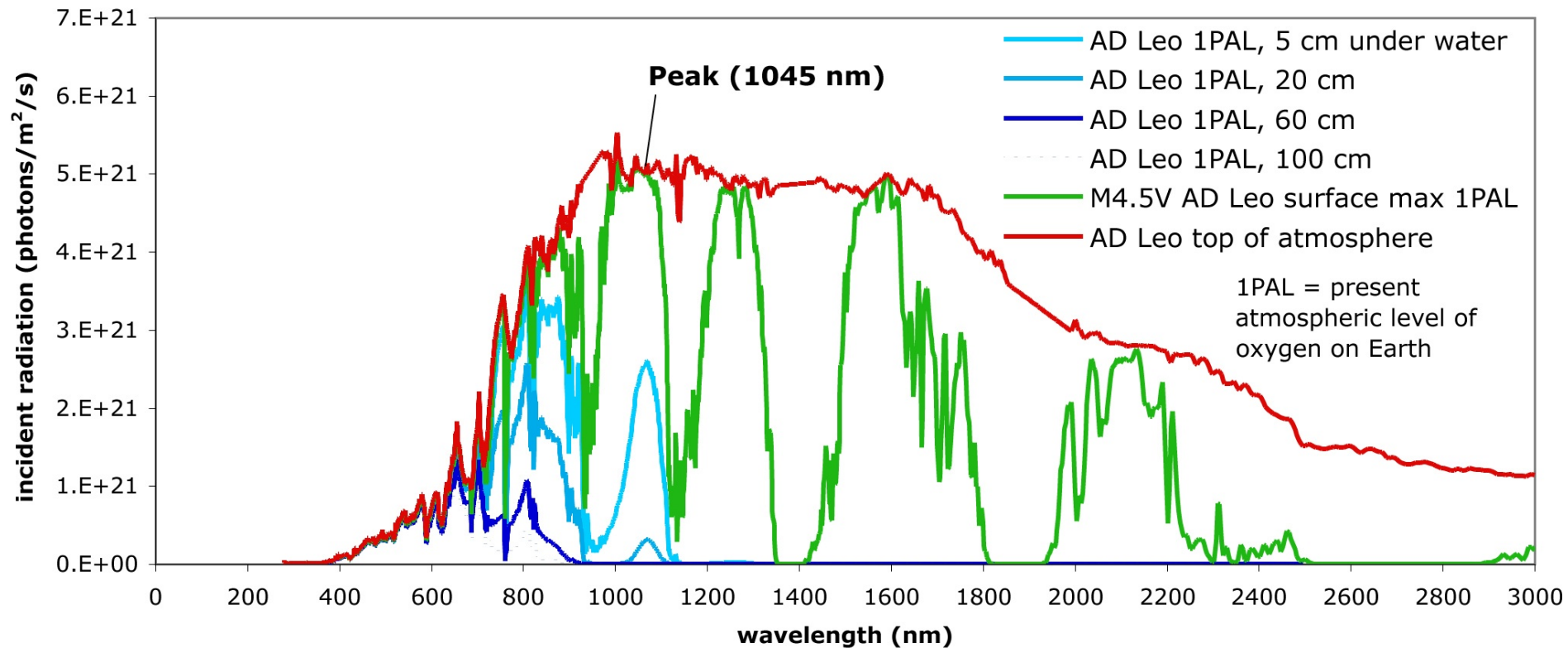
F2V Incident Radiation - With and Without Oxygen





UV Flaring M3V star: early organisms need protection under water but won't starve for light

UV Flaring M3V AD Leo Incident Radiation

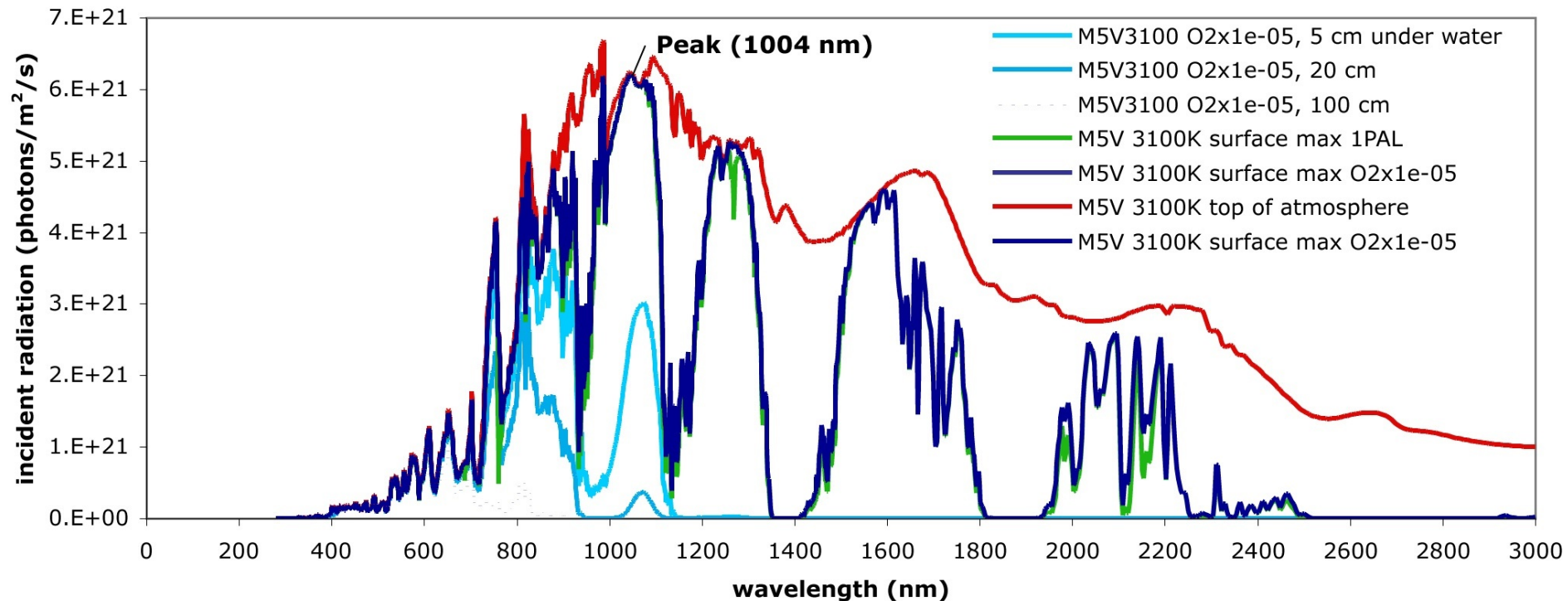


Quiescent M5V star:

low UV - no need for ozone layer

high NIR - oxygenic photosynthesis on 3+ photons, or competitive advantage for anoxygenic in the NIR on land?

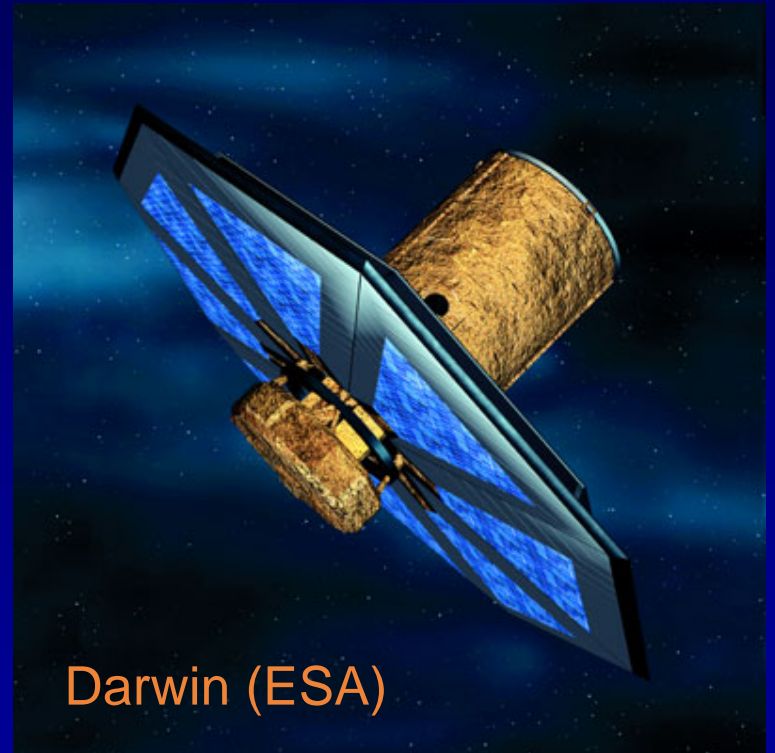
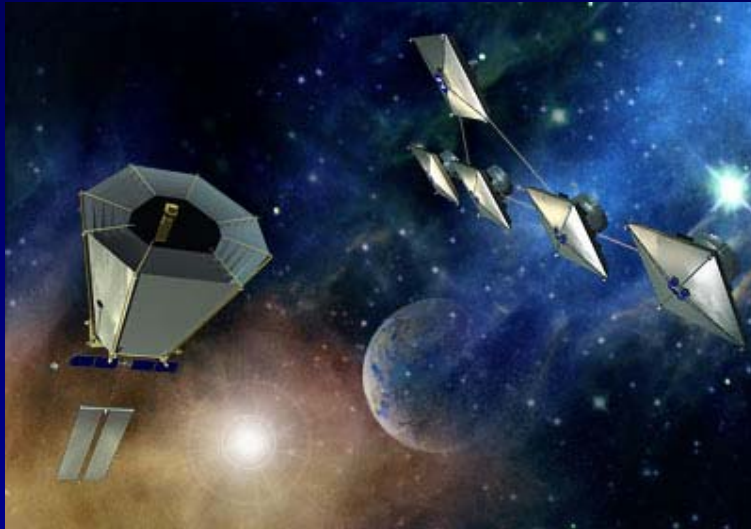
Quiescent M5V Incident Radiation





Missions to Observe Direct Planetary Spectra

Terrestrial Planet Finder (NASA)



Darwin (ESA)

Astrobiology papers (free issue!)

Kiang, N.Y., J. Siefert, Govindjee, and R.E. Blankenship. (2007). "Spectral signatures of photosynthesis I: Review of Earth organisms," *Astrobiology Special Issue on M Stars*, 7(1): 222-251.

Kiang, N.Y., A. Segura, G. Tinetti, Govindjee, R.E. Blankenship, M. Cohen, J. Siefert, D. Crisp, and V.S. Meadows. (2007). "Spectral signatures of photosynthesis II: coevolution with other stars and the atmosphere on extrasolar worlds," *Astrobiology Special Issue on M Stars*, 7(1): 252-274.

Scientific American - coming in April!

More work to do:

- Optimal pigments:
 - Modeling and lab measurements of thermodynamic efficiency of light harvesting under different available light spectra
 - Modeling of organism fitness relative to respiration losses vs. carbon gain
- Planetary spectra:
 - Modeling radiance spectra with different surface pigments and atmospheres





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